

TITLE

INORGANIC COMPOUND SOL MODIFIED BY ORGANIC COMPOUND

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FIELD OF THE INVENTION

5 The present invention relates to an inorganic compound
sol having inorganic compound particulates dispersed in a
dispersion media, which inorganic compound sol can be used
in a coating material, a hard coating agent, an insulating
coat and a protective coat of electrical and electronic
10 part, an additional agent of cement, and a binder of
inorganic fiber, etc. More particularly, the present
invention is concerned with an inorganic compound sol in
which the surface of inorganic compound particulates is
modified by a specified organic compound to thereby exhibit
15 excellent dispersion stability in dispersion media.

BACKGROUND OF THE INVENTION

Particulates of an inorganic oxide such as silica or
alumina must generally have their surface rendered
20 hydrophobic for obtaining an organic solvent dispersion
thereof. Thus, generally, the surface of such particulates
is modified.

A method of modifying the surface of such inorganic
compound particulates comprises reacting, for example, a
25 reactive monomer or a coupling agent with hydroxyl groups
of the particulate surface. This method is carried out,
for example, by dispersing powdery particulates in an
organic solvent and adding a modifier to the dispersion to

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thereby modify the particulate surface, or by conducting a solvent substitution so as to replace water of an aqueous dispersion of particulates by an organic solvent and adding a modifier to the dispersion to thereby modify the
5 particulate surface.

However, these methods cannot completely inhibit the aggregation of particulates, thereby rendering it difficult to obtain an organic solvent sol of high dispersibility.

Moreover, the problem has been encountered such that,
10 when the above inorganic compound particulates are used as a filler in, for example, a coating material, a hard coating agent component of an ^{insulating} ~~insulating~~ coat and a protective coat, adding a sol thereof to a matrix of coating film forming agent is likely to invite an
15 aggregation of particulates in the matrix. Especially, the defect has been encountered such that, when the organic solvent sol is used in the presence of cation, anion, or surfactant, particulates may be aggregated and a gelation may occur.

20 For example, for the use for the coating material, in order to improve the hardness, water resistance and stain resistance of the coating films, an organic solvent sol in which the inorganic compound particulates had been
A dispersed has been used. However, ^a ~~the~~ problem has been
25 encountered such that the coating material becomes viscous
A and whitens since such organic solvent sol is poor in ^{its} ~~the~~ compatibility with the coating film-formed resin and the resin emulsion being obtained.

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Further, for the hard coating agent, in order to improve properties of the film being formed, such as the hardness and water resistance, ~~the~~ inorganic compound particulates have been used as fillers. However, ~~the~~ ^a problem has been encountered such that ~~a~~ ^{the} hard coating film being formed ~~turns to be~~ ^{becomes} opaque since the particulates are poor in the dispersing stability in the coating solution ^{used in} ~~for~~ the coating film forming ^{process}. Also in the case that such organic solvent sol is used as a solution for an insulating film and a protective film forming for electrical and electronic components, ~~etc~~ ^{and the like}, the problem has been encountered such that the coating solution becomes viscous since the particulates are poor in ~~the~~ dispersibility in the coating solution.

Furthermore, in order to improve ~~the~~ soil strength, a sol in which ~~the~~ inorganic compound particulates had been dispersed has been added to a cement ~~to obtain~~ ^{as} a soil stabilizer. In ~~the~~ event that the sol is poor in the stability, the problem has been encountered that it has been hard to fill up crevices between the soils and moles with the inorganic compound particulates.

OBJECT OF THE INVENTION

The present invention has been made in view of the above circumstances, and ~~the~~ ^{an} object of the present invention is to provide an inorganic compound sol modified by an organic compound, which is excellent in dispersion stability.

The inorganic compound sol of the present invention comprises a dispersion medium and, dispersed therein, inorganic compound particulates whose surface has been modified by an organic compound exhibiting a molecular polarizability of from 2×10^{-40} to $850 \times 10^{-40} \text{ C}^2\text{m}^2\text{J}^{-1}$.

Further, the above dispersion medium preferably has a dielectric constant of from 10 to 85.

The present invention will be described in greater detail below.

The terminology "molecular polarizability" used herein defines the magnitude of dipole moment which is produced by a shift of negatively charged electron cloud of a molecule from the positively charged nucleus by the action of external electric field surrounding the molecule. The molecular polarizability is expressed by the formula:

$$\alpha_o = 4\pi\epsilon_o R^3 \quad (C^2m^2J^{-1})$$

wherein α_o represents the molecular polarizability, ϵ_o represents the dielectric constant, and R represents the molecular radius.

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Inorganic compound particulates

Examples of the inorganic compound particulates suitably employed in the present invention include particulates of silica, alumina, titania, zirconia and other inorganic oxides or composite oxides of these. Of the above particulates, silica particulates or composite oxides ~~be composite oxide particulates~~ composed of silica and at least one inorganic oxide other than silica such as silica/alumina and silica/zirconia are preferred. The above silica particulates can be produced by, for example, the process described in the applicant's prior applications published as Japanese Patent Publication Nos. 4(1992)-56775 and 4(1992)-55125.

Examples of the inorganic oxides other than silica include oxides of elements selected from among those of Group 1A, Group 2A, Group 2B, Group 3A, Group 3B, Group 4A, Group 4B, Group 5A, Group 5B and Group 6A of the periodic table. Specific examples thereof include Li_2O , Na_2O , K_2O , Rb_2O , BeO , MgO , CaO , ZnO , Y_2O_3 , La_2O_3 , Al_2O_3 , Ga_2O_3 , B_2O_3 , Ce_2O_3 , Sb_2O_3 , P_2O_5 , TiO_2 , ZrO_2 , SnO_2 , MoO_3 and WO_3 .

The above silica containing composite oxides can be produced by, for example, the process described in the applicant's prior applications published as Japanese Patent

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Laid-open Publication Nos. 5(1993)-132309 and 7(1995)-10522.

For example, the silica containing composite oxides can be produced by simultaneously adding an alkali metal silicate, such as sodium silicate, and an alkali soluble inorganic compound to an alkali aqueous solution having a pH value of at least 10 and reacting them without controlling the pH concentration of the reaction mixture.

Alternatively, the silica containing composite oxides can be produced by dispersing seed particulates composed of particulates of silica, alumina and other inorganic oxides in an alkali aqueous solution having a pH value of at least 10 and adding the above silicate and alkali soluble inorganic compound to the dispersion so that the particulates grow.

In the silica containing composite oxide particulates, the weight ratio of silica to inorganic oxides other than silica (SiO_2 /other inorganic oxides) preferably ranges from 0.1 to 500 and, still preferably, from 5 to 300.

The size of inorganic compound particulates for use in the present invention is not particularly limited as long as the sol containing the inorganic compound particulates is stable.

These inorganic compound particulates are preferably contained in the inorganic compound sol in an amount of from 1 to 50% by weight, still preferably, from 5 to 30% by weight.

Organic compound

In the inorganic compound sol of the present invention, the surface of the above inorganic oxide is modified by an organic compound exhibiting a molecular polarizability of from 2×10^{-40} to $850 \times 10^{-40} \text{ C}^2\text{m}^2\text{J}^{-1}$,
5 preferably, from 5×10^{-40} to $850 \times 10^{-40} \text{ C}^2\text{m}^2\text{J}^{-1}$.

Examples of the organic compounds exhibiting the above molecular polarizability include:

- vinylsilane compounds such as vinyltrimethoxysilane, vinyltriethoxysilane, vinylmethyldimethoxysilane,
10 vinylmethyldiethoxysilane and vinylphenyldimethoxysilane;
acrylsilane compounds such as γ -acryloxypropyltrimethoxysilane, γ -acryloxypropylphenyldimethoxysilane, γ -methacryloxypropyltrimethoxysilane and γ -
15 methacryloxypropylphenyldimethoxysilane;
epoxysilane compounds such as γ -glycidoxypropyltrimethoxysilane and γ -glycidoxypropylmethyldiethoxysilane;
aminosilane compounds such as γ -
20 aminopropyltriethoxysilane; and
 γ -mercaptopropyltrimethoxysilane and γ -chloropropyltrimethoxysilane.

Also, use can be made of a reactive monomer such as styrene monomer or an acrylic acid monomer, e.g., ethyl
25 methacrylate. Further, use can be made of a linear alcohol such as butanol.

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The reactive monomer may polymerize at the stage of modification, so that at least part thereof becomes a polymer.

5 The above organic compounds may be used either individually or in combination.

When the molecular polarizability of the organic compound is lower than $2 \times 10^{-40} \text{ C}^2\text{m}^2\text{J}^{-1}$, the organic properties of the organic compound are decreased so that the organic compound has low affinity with the organic solvent. Therefore, the particulates whose surface has been modified by this organic compound have poor dispersibility in the organic solvent. In particular, when an acid, a base, a salt, or a surfactant thereof is present in the inorganic compound sol, the particulates are likely to aggregate with each other.

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Dispersion media

In the inorganic compound sol of the present invention, preferred use is made of a dispersion medium (solvent) whose dielectric constant is from 10 to 85. When the dielectric constant is less than 10, the particulates are unstable in the sol, so that a gelation may occur.

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Examples of such organic solvents include water; monohydric alcohols such as ethanol, propanol and butanol; polyhydric alcohols such as ethylene glycol and propylene glycol; alcohol ethers such as ethylene glycol monoethyl ether; amide solvents such as N-methylformamide, N,N-dimethylformamide and N-methylacetamide; and lactones such as γ -butyrolactone and N-methyl-2-pyrrolidone. These

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5 An organic or inorganic acid, an organic base or
inorganic base, a salt, or a surfactant thereof may be
added to these dispersion media. Examples of suitable
organic or inorganic acids thereof include hydrochloric
acid, sulfuric acid, nitric acid, phosphoric acid,
0 perchloric acid, acetic acid. Examples of suitable organic
or inorganic bases thereof include ammonium hydroxide,
organic amine, hydroxide of alkali metals or alkali earth
metals. Examples of suitable surfactants thereof include
sodium alkylbenzenesulfonate, sodium alkylsulfonate.

The inorganic compound sol of the present invention can be prepared by the following method.

The dispersion of inorganic compound particulates may be a water dispersion, an organic solvent dispersion, or a dispersion in a mixture of water and an organic solvent. It is preferred that the inorganic compound particulates be
25 contained in the above dispersion in an amount of 0.1 to 50% by weight, especially, 1 to 20% by weight.

The surface modifying organic compound is added preferably in an amount of 0.1×10^{-6} to 50×10^{-6} mol/m²

and, still preferably, 1×10^{-6} to 30×10^{-6} mol/m² in terms of the amount of modification per outer surface area of the inorganic compound particulates dispersed in the dispersion. When the amount is less than 0.1×10^{-6} mol/m²,
5 the effect of modification is unsatisfactory. Even when the organic compound is used in amounts greater than 50×10^{-6} mol/m², the effect of modification is no longer enhanced.

In the step (b), after the addition of a specified
10 amount of surface modifying organic compound, the dispersion is heated at 50°C or higher temperatures, preferably, 60°C or higher temperatures.

Thus, the surface of the inorganic compound reacts with the surface modifying organic compound, so that the
15 modification of the surface of the inorganic compound is advanced.

In the step (c), when a dispersion medium (organic solvent) whose dielectric constant is lower than 10 is contained in the surface-modified inorganic compound sol
20 obtained above, a solvent displacement replacing it by dispersion media whose dielectric constant is at least 10 may be carried out.

The solvent displacement may be performed by the use of, for example, an ultrafilter or a rotary evaporator.
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EFFECT OF THE INVENTION

In the inorganic compound sol of the present invention, the surface of the inorganic compound

particulates is modified by the organic compound having specified molecular polarizability. Therefore, the inorganic compound particulates have desirable affinity with the dispersion media, so that the dispersion stability thereof in the dispersion media ^{is} ~~are~~ excellent without the occurrence of aggregation of particulates and gelation. Further, even if an organic or inorganic acid or a salt thereof is present in the inorganic compound sol, the inorganic compound particulates would not aggregate with each other and the gelation would not occur.

When the inorganic compound sol of the present invention is blended as a filler in, for example, a coating material or a hard coating agent ^{and} ~~even~~ if an acid, base, salt, surfactant, et al. is present ^{in the} ~~in the~~ inorganic compound sol, the finally obtained coating film is substantially free from ^a transparency decrease and cracking attributed to the aggregation of particulates and the gelation. Therefore, the inorganic compound sol of the present invention is useful as a filler to be blended in not only various coating materials and hard coating agents but also ^{various} resins. The inorganic compound sol is suitably employed as, for example, a magnetic tape filler or ^{as} ~~a~~ film blocking preventive agent.

Further, when the inorganic compound sol of the present invention is added to a cement, excessively quick caking of a cement is retarded because of a low gelation rate. The inorganic compound sol can easily fill up crevices between the soils and moles. The cement is caked

after filling. Therefore, the inorganic compound sol of the present invention is useful as an additive for cement for water stop or soil strength.

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EXAMPLE

The present invention will now be illustrated in greater detail with reference to the following Examples, which in no way limit the scope of the invention.

Example 1

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~~[Preparation of surface modified sol]~~

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500 g of a silica/alumina water dispersion sol (Catalysts & Chemicals Industries Co., Ltd., Cataloid-SN, weight ratio of $\text{SiO}_2/\text{Al}_2\text{O}_3 = 285.7$, average particle size: 12 nm and solid content: 20% by weight) was used as a starting material and subjected to a solvent displacement by means of an ultrafilter to thereby replace the water by methanol. Thus, there was obtained a methanol dispersion sol having a solid content of 30% by weight.

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300 g of this sol was mixed with 2700 g of ethanol, and 8.4 g of γ -glycidoxypropyltrimethoxysilane was added to the mixture. The mixture was agitated for 1 hr, thereby obtaining a sol containing silica/alumina particulates whose surface was modified by γ -glycidoxypropyltrimethoxysilane.

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196 g of ethylene glycol was added to the obtained sol and heated at 60°C for 1 hr. Thereafter, ethanol was removed in vacuum by the use of a rotary evaporator, thereby obtaining a surface-modified silica/alumina sol of

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~~[Evaluation of sol stability II]~~

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~~[Evaluation of sol stability III]~~

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Example 2

A surface-modified silica/zirconia sol was obtained in the same manner as in Example 1, except that a

silica/zirconia water dispersion sol (weight ratio of $\text{SiO}_2/\text{ZrO}_2$: 3, average particle size: 30 nm and solid content: 20% by weight) was used as a starting material.

The sol stability I of the obtained surface-modified silica/zirconia sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

Example 3

A surface-modified silica/titania sol was obtained in the same manner as in Example 1, except that a silica/titania water dispersion sol (weight ratio of $\text{SiO}_2/\text{TiO}_2$: 9, average particle size: 10 nm and solid content: 20% by weight) was used as a starting material.

The sol stability I of the obtained surface-modified silica/titania sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

Example 4

A surface-modified composite oxide sol was obtained in the same manner as in Example 1, except that a sol mixture consisting of 250 g of a silica/alumina water dispersion sol (weight ratio of $\text{SiO}_2/\text{Al}_2\text{O}_3$: 285.7, average particle size: 12 nm and solid content: 20% by weight) and 250 g of a silica/zirconia water dispersion sol (weight ratio of $\text{SiO}_2/\text{ZrO}_2$: 3, average particle size: 30 nm and solid content: 20% by weight) was used as a starting material.

The sol stability I of the obtained surface-modified composite oxide sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

5 Example 5

A surface-modified silica/tin oxide sol was obtained in the same manner as in Example 1, except that a silica/tin oxide water dispersion sol (weight ratio of $\text{SiO}_2/\text{SnO}_2$: 19, average particle size: 10 nm and solid content: 20% by weight) was used as a starting material and that N-methylpyrrolidone was used as a dispersion medium.

The sol stability I of the obtained surface-modified silica/tin oxide sol was evaluated in the same manner as in Example 1.

15 The results are given in Table 1.

Example 6

A surface-modified silica/indium oxide sol was obtained in the same manner as in Example 1, except that a silica/indium oxide water dispersion sol (weight ratio of $\text{SiO}_2/\text{In}_2\text{O}_3$: 5.7, average particle size: 11 nm and solid content: 20% by weight) was used as a starting material and that γ -butyrolactone was used as a dispersion medium.

The sol stability I of the obtained surface-modified silica/indium oxide sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

Example 7

A surface-modified silica/alumina sol was obtained in the same manner as in Example 1, except that 5.0 g of vinyltrimethoxysilane was used in place of 8.4 g of γ -glycidoxypropyltrimethoxysilane.

- 5 The sol stability I of the obtained surface-modified silica/alumina sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

Example 8

- 10 A surface-modified silica/antimony oxide sol was obtained in the same manner as in Example 1, except that a silica/antimony water dispersion sol (weight ratio of $\text{SiO}_2/\text{Sb}_2\text{O}_5$: 5.7, average particle size: 15 nm and solid content: 20% by weight) was used as a starting material.

- 15 The sol stability I of the obtained surface-modified silica/antimony oxide sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

Example 9

- 20 A surface-modified silica/tungsten oxide sol was obtained in the same manner as in Example 1, except that a silica/tungsten oxide water dispersion sol (weight ratio of SiO_2/WO_3 : 4, average particle size: 16 nm and solid content: 20% by weight) was used as a starting material, that 9.0 g
25 of γ -methacryloxypropyl-trimethoxysilane was used in place of 8.4 g of γ -glycidoxypropyltrimethoxysilane and that methyl cellosolve was used in place of ethylene glycol as a dispersion medium.

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The sol stability I of the obtained surface-modified silica/tungsten oxide sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

5 Example 10

The methanol-dispersed silica/alumina sol of 30% by weight in solid content which was obtained in Example 1 was diluted with methanol to a solid content of 5% by weight. 8 g of 2,2'-azobis(2-aminodipropene) dihydrochloride was added to 1000 g of the resultant sol and, further, 30 g of styrene monomer was mixed thereinto, followed by agitation at 85°C for 5 hr. Thus, there was obtained a sol comprising silica/alumina particulates whose surface was modified by polystyrene.

15 450 g of ethylene glycol was added to the obtained sol and the obtained sol was heated at 60°C for 1 hr. Thereafter, alcohol was removed in vacuum by the use of a rotary evaporator, thereby obtaining a surface-modified silica/alumina sol of 10% by weight in solid content which
20 contained ethyleneglycol as a dispersion medium.

The sol stability I of the obtained surface-modified silica/alumina sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

25 Example 11

A surface-modified silica/alumina sol was obtained in the same manner as in Example 10, except that methyl methacrylate was used in place of styrene.

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5 Example 12

340 g of n-butanol was added to 300 g of the methanol-dispersed sol of silica/alumina composite oxide (solid content: 20% by weight) prepared by the same solvent substitution as in Example 1, and a solvent displacement was carried out in vacuum. Thus, there was obtained 400 g of a sol of silica/alumina dispersed in n-butanol. This sol was heated at 150°C for 3 hr in an autoclave.

20 The sol stability I of the obtained surface-modified silica/alumina sol was evaluated in the same manner as in Example 1.

Example 13

(a) Preparation of Surface-modified soil
~~[Preparation of surface-modified soil]~~

330 g of a silica water dispersion sol (Catalysts & Chemicals Industries Co., Ltd., Cataloid-SI-30, average particle size: 12 nm and solid content: 30% by weight) as a

starting material was mixed with 170g of water and 50 g of cation-exchange resin, and followed by agitation for 30 min.

5 The cation-exchange resin separated from the mixture, and then 6.7 g of γ -glycidoxypyrpyltrimethoxysilane was added to 400 g of the obtained silica sol having pH value of 4. The mixture was agitated for 1 hr at 60°C, thereby obtaining a sol containing silica/alumina particulates whose surface was modified by γ -
10 glycidoxypyrpyltrimethoxysilane.

Thereafter, the sol containing silica particulates was concentrated in vacuum by the use of a rotary evaporator, thereby obtaining a surface-modified silica sol of 30% by weight in solid content which contained water as a
15 dispersion medium.

The sol stability II and III of the obtained surface modified silica sol was evaluated in the same manner as in Example 1.

b The results are given in Tables 2 and 3.
20 A (b) Evaluation of Sol Stability IV
~~[Evaluation of sol stability IV]~~

A mixed solution (A) which was mixed 100 parts by weight of the obtained surface-modified silica sol and 100 parts by weight of water and the other mixed solution (B) which was mixed 250 parts by weight of a portland cement
25 and 420 parts by weight of water mixed and kept at 30°C. Then the time taken until the mixture cemented was measured as the evaluation of sol stability IV.

The results are given in Table 4.

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(C) Evaluation of Sol Stability V
~~[Evaluation of sol stability V]~~

100 parts by weight of an acrylic resin emulsion produced by Union Paint Company which was dispersion having pH value of 9 of an acrylic resin of 50% by weight in aqueous solution containing surfactant was mixed with 100 parts by weight of the obtained surface-modified silica sol, and a mixture was stirred for 10 min. Then the mixture was allowed to stand in a bath kept at 70°C, and the sol stability was evaluated.

10 The results are given in Table 5.

Comparative Example 1

A silica/alumina sol containing ethylene glycol as a dispersion medium was obtained from the silica/alumina water dispersion sol of Example 1 in the same manner as in Example 1, except that any modification using an organic compound was not performed.

The sol stability I of the obtained silica/alumina sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

20 Comparative Example 2

A silica/alumina sol was obtained in the same manner as in Example 1, except that 4 g of monomethyltrimethoxysilane was used in place of 8.4 g of γ -glycidoxypyrpyltrimethoxysilane.

25 The sol stability I of the obtained silica/alumina sol was evaluated in the same manner as in Example 1.

The results are given in Table 1.

Comparative Example 3

A silica/zirconia sol was obtained from the silica/zirconia water dispersion sol (weight ratio of $\text{SiO}_2/\text{ZrO}_2$: 3, average particle size: 30 nm and solid content: 20% by weight) of Example 2 in the same manner as
5 in Example 2, except that any surface modification using an organic compound was not performed and that N-methylpyrrolidone was used as a dispersion medium.

The sol stability I of the obtained silica/zirconia sol was evaluated in the same manner as in Example 1.

10 The results are given in Table 1.

Comparative Example 4

The sol stability II, III, IV and V of a silica water dispersion sol (Catalysts & Chemicals Industries Co., Ltd., Cataloid-SI-30, average particle size: 12 nm and solid
15 content: 30% by weight) was evaluated in the same manner as in Example 13.

The results are given in Tables 2 to 5.

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Table 1

	Sol composition	Modifying organic compound	
			mol. polarizability
Ex. 1	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	γ -glycidoxypentyl trimethoxysilane	10.4×10^{-40}
Ex. 2	$\text{SiO}_2 \cdot \text{ZrO}_2$	γ -glycidoxypentyl trimethoxysilane	10.4×10^{-40}
Ex. 3	$\text{SiO}_2 \cdot \text{TiO}_2$	γ -glycidoxypentyl trimethoxysilane	10.4×10^{-40}
Ex. 4	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$ + $\text{SiO}_2 \cdot \text{ZrO}_2$	γ -glycidoxypentyl trimethoxysilane	10.4×10^{-40}
Ex. 5	$\text{SiO}_2 \cdot \text{SnO}_2$	γ -glycidoxypentyl trimethoxysilane	10.4×10^{-40}
Ex. 6	$\text{SiO}_2 \cdot \text{In}_2\text{O}_3$	γ -glycidoxypentyl trimethoxysilane	10.4×10^{-40}
Ex. 7	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	vinyltrimethoxy silane	4.0×10^{-40}
Ex. 8	$\text{SiO}_2 \cdot \text{Sb}_2\text{O}_5$	vinyltrimethoxy silane	4.0×10^{-40}
Ex. 9	$\text{SiO}_2 \cdot \text{WO}_3$	γ -methacryloxy propyltrimethoxy silane	12.7×10^{-40}
Ex. 10	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	polystyrene	8.5×10^{-38}
Ex. 11	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	polymethyl methacrylate	4.8×10^{-40}
Ex. 12	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	n-butanol	7.3×10^{-38}
Comp. Ex. 1	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	---	
Comp. Ex. 2	$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3$	monomethyl trimethoxysilane	1.9×10^{-40}
Comp. Ex. 3	$\text{SiO}_2 \cdot \text{ZrO}_2$	---	

Table 1 (cont.)

	Dispersion medium		Stability I	
		dielectric constant	sulfuric acid	hydrochloric acid
Ex. 1	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 2	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 3	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 4	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 5	N-methyl pyrrolidone	32	stable at least 6 mo.	stable at least 6 mo.
Ex. 6	γ -butyro lactone	39	stable at least 6 mo.	stable at least 6 mo.
Ex. 7	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 8	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 9	methyl cellosolve	17	stable at least 6 mo.	stable at least 6 mo.
Ex. 10	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 11	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Ex. 12	ethylene glycol	38	stable at least 6 mo.	stable at least 6 mo.
Comp. Ex. 1	ethylene glycol	38	visc. up 15 days	visc. up 20 days
Comp. Ex. 2	ethylene glycol	38	gelled 30 days	gelled 40 days
Comp. Ex. 3	N-methyl pyrrolidone	32	gelled 20 days	gelled 20 days

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Table 2

	Sol composition	Modifying organic compound	mol. polarizability
Ex. 1	SiO ₂ ·Al ₂ O ₃	γ-glycidoxypopyl trimethoxysilane	10.4 x 10 ⁻⁴⁰
Comp. Ex. 2	SiO ₂ ·Al ₂ O ₃	-	-
Ex. 13	SiO ₂	γ-glycidoxypopyl trimethoxysilane	10.4 x 10 ⁻⁴⁰
Comp. Ex. 4	SiO ₂	-	-

Table 2 (cont.)

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	Dispersion medium	dielectric constant	Stability II (day)
Ex. 1	ethylene glycol	38	62
Comp. Ex. 1	ethylene glycol	38	4
Ex. 13	water	77	43
Comp. Ex. 4	water	77	2

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Table 3

	Sol composition	Modifying organic compound	mol. polarizability
Ex. 1	SiO ₂ ·Al ₂ O ₃	γ-glycidoxypropyl trimethoxysilane	10.4 x 10 ⁻⁴⁰
Comp. Ex. 1	SiO ₂ ·Al ₂ O ₃	-	-
Ex. 13	SiO ₂	γ-glycidoxypropyl trimethoxysilane	10.4 x 10 ⁻⁴⁰
Comp. Ex. 4	SiO ₂	-	-

Table 3 (cont.)

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	Dispersion medium	dielectric constant	Stability III (day)
Ex. 1	ethylene glycol	38	14
Comp. Ex. 1	ethylene glycol	38	1
Ex. 13	water	77	41
Comp. Ex. 4	water	77	2

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Table 4

	Sol composition	Modifying organic compound	mol. polarizability
Ex. 13	SiO ₂	γ -glycidoxypopyl trimethoxysilane	10.4×10^{-40}
Comp. Ex. 4	SiO ₂	-	-

Table 4 (cont.)

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	Dispersion medium	dielectric constant	Stability IV (min)
Ex. 13	water	77	2880
Comp. Ex. 4	water	77	60

Table 5

	Sol composition	Modifying organic compound	mol. polarizability
Ex. 13	SiO ₂	γ -glycidoxypopyl trimethoxysilane	10.4×10^{-40}
Comp. Ex. 4	SiO ₂	-	-

Table 5 (cont.)

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	Dispersion medium	dielectric constant	Stability V (day)
Ex. 13	water	77	60
Comp. Ex. 4	water	77	2